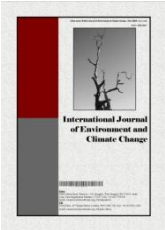

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Appraisal of Buckwheat (*Fagopyrum esculentum* L.) Genotypes for Growth, Yield, Yield Attributes, Seed and Seedling Characteristics under Prayagraj Agro-Climatic Conditions

Palagulla Venkata Mahendra Reddy [aφ*], Abhinav Dayal [a#], Neha Thomas [a#] and Narendra Reddy Ippala [aφ]

[a] Department of Genetics and Plant Breeding, NAI, SHUATS, Prayagraj, U.P, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Buckwheat is referred as poor man's food because it has good fibre, carbohydrates and essential amino acids. So, it must be made as an integral crop in agriculture production system. For this purpose, production is to be improved through development and breeding of new varieties. So, an experiment was conducted by using 26 buckwheat genotypes to evaluate them under Prayagraj agro-climatic conditions during 2021-22 to study growth, yield and yield attributes. The field experiment was conducted in randomized block design (RBD) with three replications and lab experiments were conducted in complete randomized design (CRD) with four replications. During the field experiment all genotypes showed wide variations among them for both growth and yield attributing traits. Among twenty-five genotypes, IC 108508 produced highest yield plot^{-1} (405g) followed by IC 26755 (315g), IC 37275 (299.3g) and IC 107575 (277.3g) higher yield than check PRB 1 (208.3 g). These genotypes also showed high to moderate values for growth and yield attributes. Therefore, these genotypes can be suggested for cultivation under Prayagraj agro-climatic conditions. Under laboratory study, it was observed that IC 42412 performed better for germination percent (97%), seedling length (27.9cm), fresh weight (1.05g), dry weight (0.303 g), vigour index I (2703), vigour index II (29.39), viability percent (99%) and electrical conductivity

[φ] M.Sc. Scholar;
[#] Assistant Professor;
**Corresponding author: E-mail: reddymahendra127@gmail.com;*

($0.22dsm^{-1}$). The highest protein content (14.1g%) was recorded in IC 24300 genotype. Therefore, IC 42412 can be considered as physiologically potential genotype. Through correlation and path analysis it was clear that number of seeds $plant^{-1}$, inflorescence length, economic yield, number of inflorescence $plant^{-1}$ and days to maturity may be considered for selection in crop improvement. Through this study it was concluded that IC 108508, IC 26755, IC 37275, IC 107575 and IC 42412 can be used for further breeding programs.

Keywords: Buckwheat; yield attributes; correlation and path analysis; seedling characteristics.

1. INTRODUCTION

Buckwheat (*Fagopyrum esculentum* L.) has been a crop of secondary importance in many countries and being cultivated in every growing country. It is an underutilized and neglected crop from the last decades. It is very old plant that is used as human or animal feed for more than 7000 years. It is an annual, dicotyledon plant from the family of Polygonaceae [1]. It is a climatic resilient crop and has the ability to grow under adverse climatic and poor soil conditions. Now-a-days, buckwheat gave a strong comeback due to the demand of gluten-free diet. It thrives well in different cropping pattern due to its short duration nature (3-4 months) [2]. It is cultivated as a summer crop in higher altitudes and as winter crop in lower altitudes. Buckwheat seeds are capable to germinate in extreme dry conditions. The optimum temperature required for germination is 25-28^{o}C and slightly high temperature (above 30^{o}C) at reproductive stage may result in floral abscission, poor grain quality and fruit abscission (Drazic et al*.,* 2016). It is cultivated in number of countries like Russia, China, USA, Canada, France, Germany, UK, Brazil, Australia, Japan, Sweden, Nepal and Bhutan. In India, buckwheat is cultivated widely in hilly areas. The buckwheat was grown in 2.4 M hac area world wise with production of 2.4 million tonnes and productivity of 2.4 1000 kg/hac. The leading producer of buckwheat is Russia in both area and production (1.12 m hac and 1.19 m tonnes respectively) followed by China and Ukraine. The highest productivity of buckwheat was recorded in France (3735 kg/hac) [3]. Buckwheat being highly balanced with carbohydrates and proteins is an indispensable source of sustainable agriculture for the farmers in hilly areas. Compared to the other cereals buckwheat kernel has higher fibre content. It could be nutritionally important to diabetics, as it helps to flatten the glycerine response curve and release of glucose from starch could prolong endurance during physical activities and the duration of satiety is prolonged as well (Skrabanja and Kreft, 1998). Buckwheat seeds contains variety of nutrients, main compounds are starch 70 to 91% in flour. Starch is 25% amylose and 75% amylopectin and 7 to 37% of resistant starch [1]. Protein content is around 15% with biological values above 90%. The buckwheat flour is gluten free [4], contains proteins with good balanced amino acids (Selimovic et al*.,* 2014) and it is particularly rich in lysine and arginine (Christa, K. and Soral-Smietana, M. 2008).

The identification of a cultivar importance in both national and international programmes. Different cultivars are certified on the basis of various agronomic traits (plant growth, yield traits, seed and Seedling characteristics). So, the relation and impact of these traits on yield has to be given dew consideration for developing a variety. This can be found through correlation and path analysis. The seed also should be of good quality means high germination percent, vigour, viability and must be genetically and physically pure, it was also found that those obtained from high quality seed produced 18% higher yield than those obtained from low quality seeds [5]. With technological advances in modern agriculture, each seed should readily germinate and produce a vigorous and healthy seedling ensuring maximum yield. The seed yield and chemical composition of buckwheat depends on a large number factors and some of them are variety of buckwheat and agro-climatic conditions of cultivation, Prayagraj has a sub-tropic climatic in the agro-climatic zones. So, it is suitable to cultivate buckwheat during winter in Prayagraj as a rabi season crop. With this background, the present evaluation for growth, yield, yield attributes, seed and seedling characteristics were carried out involving 26 genotypes and to determine suitable genotypes for agro-climatic region of Prayagraj.

2. MATERIALS AND METHODS

2.1 Plant Material

The planting material include IC 381463, IC 341672, IC 258233, IC 108508, IC 582972, IC 582990, IC 107575, IC 582984, IC 107616, IC

37275, IC 329201, IC 329456, IC 37296, EC 125940, IC 341679, IC 26755, IC 318859, NIC 8817, IC 24300, IC 329196, IC 42412, IC 14889, IC 37312, IC 26600 and IC 329195 buckwheat genotypes along with one check variety PRB 1 procured from National Bureau of Plant Genetic Resources (NBPGR), Shimla.

2.2 Experimental Site and Design

The study was conducted during rabi season 2021-22 at Field Experimentation Centre and State Seed Testing Laboratory of Department of Genetics and Plant Breeding, Sam Higginbottom University of Agriculture, Technology and sciences, Prayagraj located at latitude 25.350 N, longitude 82.250 E and at an altitude of 78 m from mean sea level. The soil is sandy loam in texture with moderate water holding capacity having pH ranging from 7.0 to 8.0. Field experiment was laid down using randomised block design (RBD) in three replications sown at 20 x10 cm spacing. Laboratory experiments were conducted in completely randomised design (CRD) in four replications for germination test, tetrazolium test, electric conductivity test and protein estimation test to determine physiological potentiality of genotypes.

2.3 Observations Recorded

Observations were recorded for each genotype in each replication on parameters viz., field emergence, days to first flowering, days to maturity, harvest index, seed yield plot^{-1} (g) and seed yield hectare^{-1} (qt). The observations on five randomly selected plants in each replication were taken on characters viz., first node height (cm), plant height 30 and 85 DAS (cm), number of branches plant^{-1}, number of inflorescence plant^{-1}, inflorescence length (cm), economic yield (g) and biological yield (g). Seedling parameters were determined according to standard procedures i.e., between paper method by placing 50 seeds in each replication placed in germination chamber with the application of standard temperature 20 to 25^{o}C for 10 days with 95% relative humidity (ISTA, 2015). Data recorded were gemination percent (%), shoot length (cm), root length (cm), seedling length (cm), fresh weight (g), dry weight (g), vigour index I and II.

Seed quality parameters include tetrazolium test, electric conductivity test and protein content estimation. Tetrazolium test was conducted to determine seed viability [6,7]. Seeds from each genotype were soaked overnight (18 hours) in distilled water, after which water was separated and seed coat was removed without damaging embryo. Softened seeds without seed coat were immersed in 1% aqueous tetrazolium (2,3,5-triphenyl tetrazolium chloride) solution in petri dish or beaker and incubated in dark for 3 hours at room temperature. After completion of 3 hours seeds were rinsed twice with distilled water and examined for seed viability. The 2,3,5 tetrazolium chloride imbibed by the living cells in seed is reduced to form triphenyl formazan, a stable and non-diffusible red coloured appearance can be seen. In case of dead seeds straining does not occur so no colour is appeared. The cells with varying properties of embryo stained and classification was done using standard laid by ISTA and viability percent was recorded (%) (Agarwal, 1995).

Electric conductivity test was done to determine vigour of seeds. To conduct EC test seeds were surface sterilized with 1% mercuric chloride ($HgCl_2$) solution for about ten minutes. Seeds were then taken out, washed and then taken out, washed and then soaked in 100 ml distilled water for 24 hours in an incubator. The seeds were then removed from water with help of forceps and solution left in beaker was referred as leachate [8,9]. Then electric conductivity of leachate was measured by a wheat stone type conductivity bridge (Elico CM82T) and was expressed in dsm^{-1}. The seed leachate with less electric conductivity were referred as more vigorous (Stan Mathews, 1925).

Protein content of a seed sample can be determined through lowry's method 1951 [10-12]. To determine protein content seed sample of 0.2 g should be ground with a suitable solvent system in a pestle and mortar. The ground sample is centrifuge and supernatant is used for further protein content estimation. The standard samples of Bovine serum albumin (BSA) 0.2, 0.4, 0.6, 0.8, 1.0ml were taken and make up to 1ml by filling distilled water. Take centrifuged genotype samples (0.5ml) and make up to 1ml by filling distilled water. Later, blank sample, standard samples and genotype samples were filled with 5ml of reagent C (alkaline copper solution) and incubated for 10 minutes. After incubation 0.5ml reagent D (folin-ciocalteau reagent) was added to each sample and incubated for 30 minutes. Finally, absorbance at 660nm was observed in spectrophotometer and O.D were recorded.

2.4 Statistical Analysis

Field and lab replicated data were subjected to statistical analysis by the application of f-test and one-way analysis of variance (ANOVA) at 5% probability level, using OPSTAT [13]. Correlation and Path analysis were performed in window-stat version 9.3.

3. RESULTS AND DISCUSSION

3.1 Growth Attributes

As stated in Table 1, the analysis of variance for all the characters revealed significant differences among all genotypes. The field emergence was found to be significant and maximum was observed in IC 24300 genotype (75.3%) whereas minimum was observed in IC 318859 (27.4%) genotype. The first node height was found to be significant and maximum first node height was recorded in genotype EC 12940 (9.3cm). Minimum was recorded in IC 318859 (0.9cm) genotype. The plant height was found to be significant and maximum was recorded by genotype EC 125940 (11.1cm) for 30 DAS and IC 26755 genotype (99.8cm) for 85 DAS. Minimum was recorded by genotype IC 582972 (1.1cm and 14.9cm) for both 30 and 85 DAS. The number of branches plant^{-1} were found to be significant and maximum was recorded in IC 341672 (8.7) genotype whereas, minimum was recorded in EC 125940 (1.7) genotype. Basically, plant height is an index for vigour which contributes towards productivity. The plant growth also serves as a guide to determine suitable planting population per unit area for harvesting maximum yield. A range of high variability in above characters desirable for selecting genotypes for earliness. Similar results were also reported by Aubert et al*.,* [14], Sowmya, S. A. et al*.,* [15], Misra et al*.,* [16], Bisht et al*.,* [17,18] and Debnath et al*.,* [19].

3.2 Reproductive Attributes

According to Table 1 among 26 genotypes days to flowering data was found to be significant and early flowering was reported in EC 125940 (31 DAS) and IC 37275 (32 DAS) which is comparatively earlier than check PRB 1. Delayed flowering was observed in IC 582972 (75 DAS) followed by IC 329201 (71 DAS) and IC 26600 (60 DAS). The data for days to maturity was found to be significant and EC 125940 genotype matured earlier (60 DAS) whereas, delayed maturity was observed in IC 26600 (108 DAS) genotype. Two genotypes namely IC 582972 and IC 329201 did not mature due to delayed flowering and increase in temperature. So, these two genotypes did not produce any yield. Similar results were also reported by Albert et al*.,* (2021), Sowmya, S. A. et al*.,* 15], Bisht et al*.,* [17,18] and Debnath et al*.,* [19].

3.3 Yield Attributes

Among all 26 genotypes the number of inflorescence plant^{-1} was found to be significant and maximum was recorded by genotype IC 37275 (77.7) whereas, minimum was recorded by EC 125940 (6.9). the data for length of inflorescence was found to be significant and maximum length was measured in IC 341672, IC 258233 and NIC 125940 (3.2cm). Minimum length was measured in EC 125940 (1.9cm). The data for number of seeds plant^{-1} was found to be significant and maximum was recorded in genotype IC 14889 (301.53) whereas minimum was recorded in EC 125940 (5.53). The data for biological yield was found to be significant and maximum biological yield was recorded by IC 37275 (47.27g) genotype. Minimum was recorded by EC 125940 (10.49 g). The data for economic yield was found to be significant and maximum was recorded by genotype IC 582984 (5.8g) whereas, minimum was recorded by EC 125940 (0.5g). The data for harvest index was found to be significant and maximum was recorded by genotype NIC 8817 (301.53). Minimum was recorded by EC 125940 (4.25). Seed yield plot^{-1} data was found to be significant and maximum yield was recorded in IC 108508 (405g) whereas minimum was recorded in EC 125940 (16.7g). the data for seed yield hectare^{-1} was found to be significant and maximum yield was recorded in IC 108508 (10.1qt). Minimum yield was recorded in EC 125940 (0.4 qt). The test weight data was found to be significant and maximum weight was observed in IC 42412 genotype (26.6g). Minimum was observed in EC 125940 (14.1g). Seed yield is a major determinant variable for selecting a particular variety for its commercialization and income generation capability in across all genotypes and the check. Extent of variability in above findings might be due to different genetic makeup of genotypes and various area of adaptation coupled with environmental interaction. Variation in above characters were also reported by Dubey et al*.,* [20], Bisht, A. S. et al*.,* [17,18], Dutta et al*.,* [21] and Naseem et al*.,* (2007).

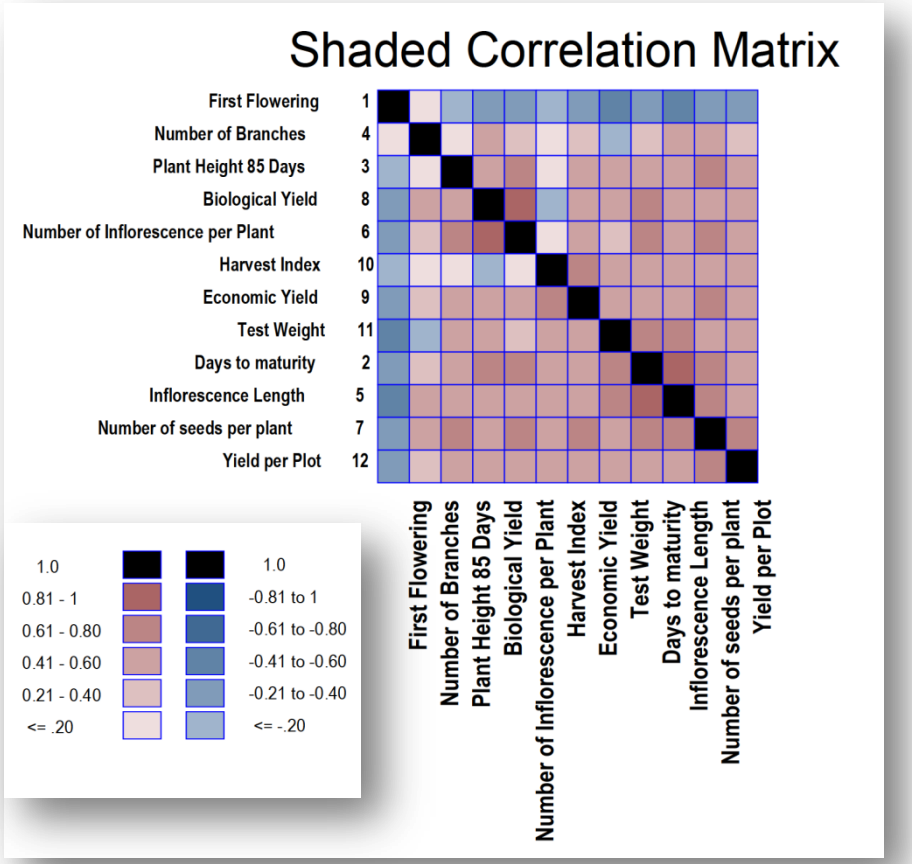

Fig. 1. Phenotypic shaded correlation matrix for yield plot^{-1}

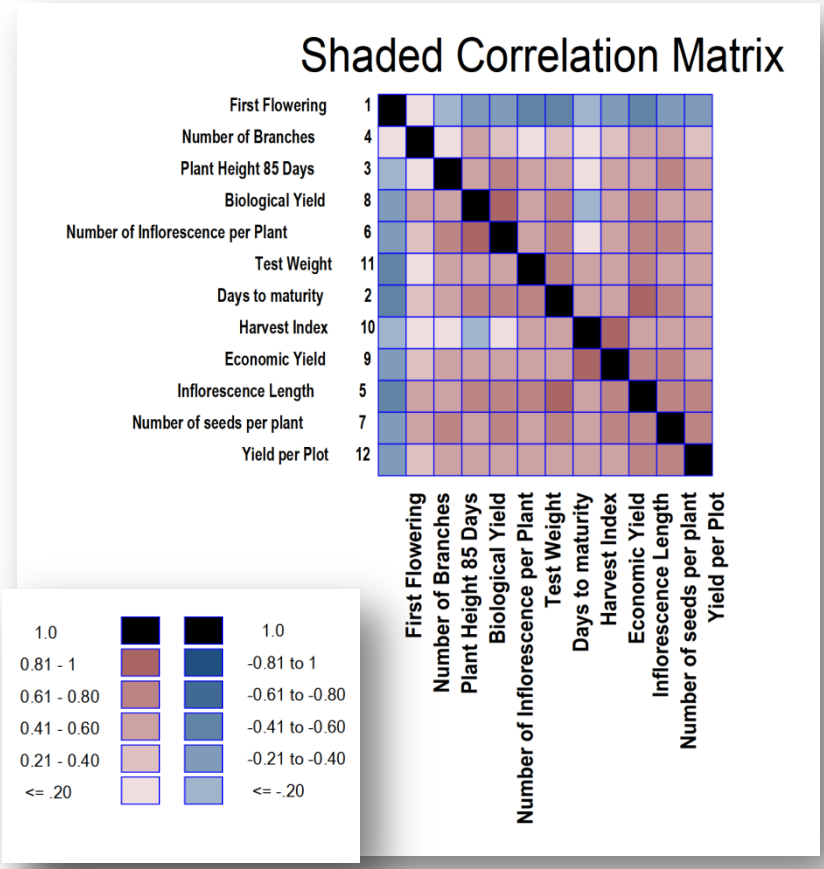

Fig. 2. Genotypic shaded correlation matrix for yield plot^{-1}

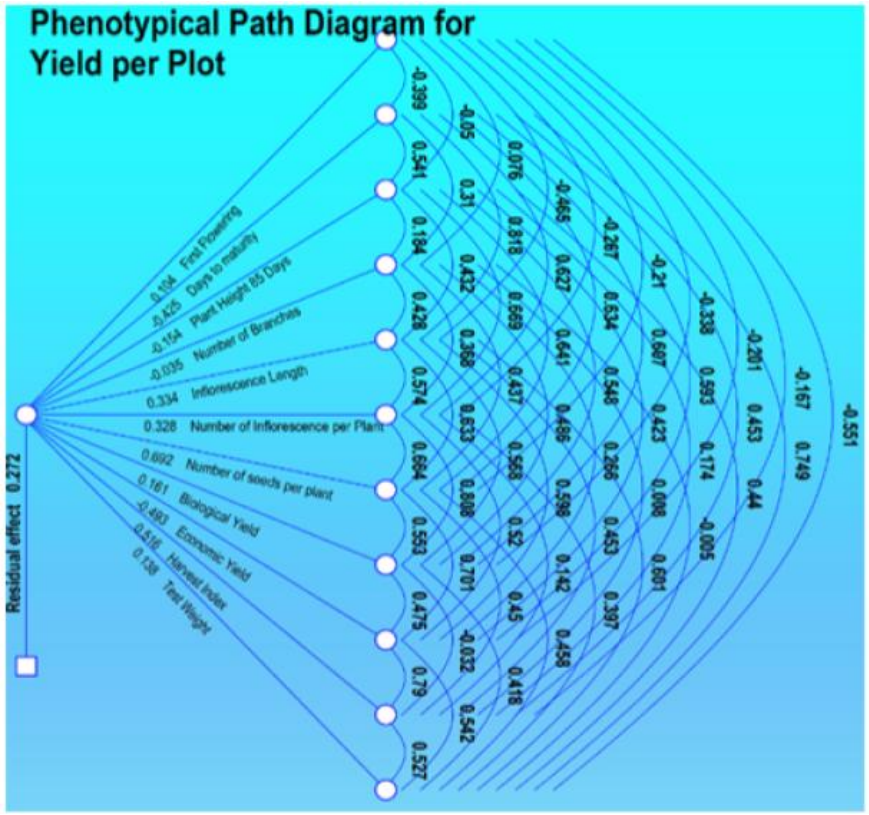

Fig. 3. Phenotypic path diagram for yield plot^{-1}

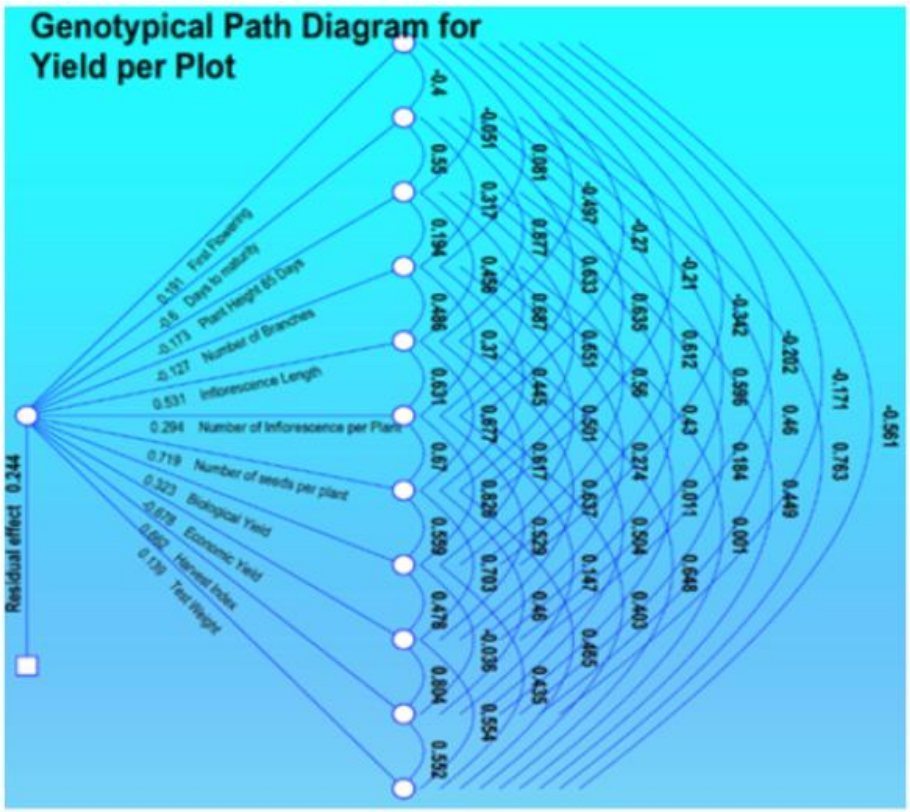

Fig. 4. Genotypic path diagram for yield plot^{-1}

Table 1. Mean performance of 25 buckwheat genotypes for field parameters during rabi 2021-22

Genotype Name	FE (%)	FNH (cm)	FF	PH (cm)		NBP	DM	NIP	LI (cm)	NSP	BY (g)	EY (g)	HI (%)	TW (g)	YP (g)	YH (g)
				30 DAS	85 DAS											
IC - 381463	57.0	3.1	39	5.2	24.6	5.3	71	16.6	2.8	92.80	18.49	1.7	9.19	19.0	92.3	2.3
IC - 341672	47.4	2.6	37	3.9	40.2	8.7	77	32.7	3.2	228.00	30.48	3.3	11	13.9	237.7	5.9
IC - 258233	50.4	2.2	50	3.7	47.4	5.7	95	31.2	3.2	264.20	25.69	5.4	21.7	15.8	271.7	6.8
IC - 108508	61.4	2.9	52	4.4	40.7	5.2	85	28.5	2.5	187.73	14.37	4.5	31.94	24.4	405.0	10.1
IC - 582972	59.6	1.0	75	1.1	14.9	4.2	0	0	0	0	0	0	0	0.0	0	0
IC - 582990	55.4	2.3	39	3.9	46.8	7.1	71	29.5	3.1	159.13	19.01	2.4	12.84	14.6	160.7	4.0
IC - 107575	71.6	2.9	42	4.1	48.5	5.7	74	45.9	2.8	171.20	23.75	2.6	11.44	15.2	277.3	6.9
IC - 582984	59.4	2.6	41	3.9	25.6	5.1	74	26.7	2.5	35.60	17.19	5.8	34.52	16.5	24.0	0.6
IC - 107616	66.5	2.2	54	4.1	44.4	4.9	92	31.9	2.9	110.47	10.25	1.7	17.63	15.8	179.7	4.5
IC - 37275	68.4	2.0	32	4.1	73.1	5.5	74	77.7	2.7	235.07	47.27	3.9	8.22	17.7	299.3	7.5
IC - 329201	60.4	0.9	71	1.3	24.2	5.3	0	0	0	0	0	0	0	0	0	0
IC - 329456	64.5	2.3	35	4.0	45.3	5.6	80	45.1	2.7	149.00	36.75	2.6	7.04	17.6	172.3	4.3
IC - 37296	54.5	2.7	36	4.3	53.5	5.3	76	32.5	2.3	210.00	29.04	4.4	15.42	22.2	120.3	3.0
EC - 125940	52.7	9.3	31	11.1	27.5	1.7	60	6.9	1.3	5.53	10.49	0.5	4.25	14.1	16.7	0.4
IC - 341679	59.6	2.3	38	4.0	38.9	4.7	73	33.5	2.5	91.60	16.63	1.4	8.34	16.1	116.3	2.9
IC - 26755	69.5	2.5	40	4.4	99.8	4.5	76	41.6	3.0	226.93	20.77	3.8	18.55	16.9	315.0	7.9
IC - 318859	27.4	2.9	45	4.2	47.8	5.5	90	30.0	2.3	90.93	20.76	2.1	10.27	23.7	96.0	2.4
NIC - 8817	64.8	2.8	51	4.9	67.0	4.6	76	35.1	3.2	256.73	15.33	5.7	37.57	22.5	265.3	6.6
IC - 24300	75.3	2.3	39	3.7	37.7	4.5	70	24.3	2.9	132.80	19.07	2.7	14.83	20.9	103.3	2.6
IC - 329196	34.0	2.3	50	3.7	74.4	5.7	82	31.9	2.8	105.27	19.96	1.7	8.64	16.9	79.7	2.0
IC-42412	47.7	5.8	40	7.7	71.1	2.9	68	25.0	1.7	112.27	19.50	2.8	14.69	26.7	93.7	2.3
IC-14889	67.6	2.6	41	3.3	66.9	5.5	93	33.0	2.4	301.53	13.73	3.4	25.14	20.1	171.0	4.3
IC-37312	58.5	2.1	46	4.0	67.7	6.4	81	45.4	2.3	162.20	26.11	3.1	12.13	20.2	152.0	3.8
IC-26600	71.5	1.7	69	2.4	94.8	7.7	108	53.5	3.0	223.47	46.83	4.1	9.02	18.2	160.7	4.0
IC-329195	64.8	3.6	37	4.4	45.6	6.2	65	20.3	2.5	153.73	18.88	3.1	17.45	20.8	235.0	5.9
PRB-1 (Check)	66.5	2.7	33	4.7	49.1	6.2	79	19.7	3.0	110.07	26.79	2.5	18.7	23.0	208.3	5.2
MAX	**75.3**	**9.3**	**75.0**	**11.1**	**99.8**	**8.7**	**108**	**77.7**	**3.20**	**301.53**	**47.27**	**5.8**	**37.57**	**26.7**	**405**	**10.1**
MIN	**27.4**	**0.9**	**31.0**	**1.1**	**14.9**	**1.7**	**60.0**	**6.9**	**1.30**	**5.53**	**10.49**	**0.5**	**4.25**	**14.1**	**16.7**	**0.4**
SEm ±	**0.5**	**0.1**	**0.49**	**0.2**	**2.0**	**0.17**	**0.7**	**1.3**	**0.18**	**1.84**	**1.0**	**0.1**	**1.13**	**0.67**	**5.44**	**0.1**

Genotype Name	FE (%)	FNH (cm)	FF	PH (cm)		NBP	DM	NIP	LI (cm)	NSP	BY (g)	EY (g)	HI (%)	TW (g)	YP (g)	YH (g)
				30 DAS	85 DAS											
CD	**1.4**	**0.2**	**1.38**	**0.7**	**5.6**	**0.49**	**1.88**	**3.7**	**0.53**	**5**	**2.72**	**0.3**	**3.21**	**1.91**	**15.46**	**0.4**
F-Test (p=0.05)	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**
CV%	**1.44**	**5.3**	**1.87**	**9.34**	**6.7**	**5.59**	**1.57**	**7.2**	**12.1**	**2.1**	**7.88**	**5.14**	**13.4**	**6.67**	**5.71**	**5.76**

***FE**: Field emergence, **FNH**: First node height, **FF**: Days to first flowering, **DM**: Days to maturity, **PH**: Plant height, **NB**: Number of branches per plant, **IL**: Inflorescence length, **NIP**: Number of inflorescences per plant, **NSP**: Number of seeds per plant, **BY**: Biological yield, **EY**: Economic yield, **HI**: Harvest index, **TW**: Test weight, **YP**: Yield per plot and **YH**: Yield per plot*

Table 2. Mean performance of 24 buckwheat genotypes for seed and seedling parameters conducted in state seed testing laboratory

Genotype Name	Germination (%)	Root Length (cm)	Shoot Length (cm)	Seedling Length (cm)	Fresh Weight (g)	Dry Weight (g)	Vigour Index I	Vigour Index II	Seed Viability (%)	Electric Conductivity (dsm-1)	Protein (g%)
IC - 381463	80.5	10.7	10.8	21.50	0.59	0.15	1731	12.08	84	0.28	12.8
IC - 341672	92.5	10.6	9.1	19.70	0.49	0.13	1822	12.03	93	0.23	12.6
IC - 258233	96	12.1	11	23.10	0.53	0.14	2218	13.92	96	0.23	10.6
IC - 108508	95.5	11.6	12.5	24.10	0.71	0.16	2302	16.04	96	0.32	13.3
IC - 582990	91	10.9	9.2	20.10	0.59	0.17	1829	15.93	94	0.23	12.1
IC - 107575	95.5	13.05	11	24.06	0.55	0.16	2297	15.76	95	0.24	11.0
IC - 582984	81	9.1	10.4	19.50	0.46	0.12	1580	10.21	84	0.24	10.5
IC - 107616	90.3	10.7	10.7	21.40	0.49	0.13	1931	11.82	93	0.23	10.3
IC - 37275	88	11.6	11.6	23.20	0.51	0.12	2042	11.00	93	0.23	11.4
IC - 329456	94.5	11.3	10.6	21.90	0.58	0.14	2070	13.99	94	0.26	10.4
IC - 37296	88.5	11.9	11.5	23.40	0.7	0.17	2071	15.31	90	0.3	13.1
EC - 125940	73.5	3.9	11.8	15.70	0.3	0.08	1154	6.17	82	0.21	11.2
IC - 341679	90.2	12.4	9.2	21.60	0.47	0.14	1949	13.54	92	0.22	10.3
IC - 26755	94.5	9.6	10.1	19.70	0.63	0.16	1862	15.12	96	0.23	13.3
IC - 318859	83.3	9.4	10.5	19.90	0.71	0.17	1657	14.24	87	0.28	12.1
NIC - 8817	87	11	11.7	22.70	0.47	0.16	1975	14.18	92	0.24	10.5
IC - 24300	82	11.4	11.1	22.50	0.6	0.15	1845	12.71	93	0.26	14.1
IC - 329196	93.5	7.4	9.5	16.90	0.5	0.14	1580	13.56	96	0.20	13.3
IC-42412	97	12.3	15.4	27.70	1.05	0.303	2687	29.39	99	0.22	12.9
IC-14889	94.5	11.6	11.6	23.20	0.63	0.15	2192	14.55	96	0.31	12.4
IC-37312	95.5	8.8	12.1	20.90	0.7	0.16	1996	15.95	97	0.21	12.9
IC-26600	86.5	11.1	10.8	21.90	0.62	0.14	1894	12.80	91	0.25	13.7
IC-329195	96.5	11.5	11.6	23.10	0.76	0.17	2229	16.98	98	0.23	10.4
PRB-1	94.8	12	10.7	22.70	0.82	0.07	2151	6.92	98	0.24	13.4
MAX	**97.0**	**13.0**	**15.4**	**27.7**	**1.05**	**0.303**	**2687**	**29.39**	**99**	**0.31**	**14.1**

Genotype Name	Germination (%)	Root Length (cm)	Shoot Length (cm)	Seedling Length (cm)	Fresh Weight (g)	Dry Weight (g)	Vigour Index I	Vigour Index II	Seed Viability (%)	Electric Conductivity (dsm-1)	Protein (g%)
MIN	**73.5**	**3.9**	**9.1**	**15.7**	**0.3**	**0.08**	**1154**	**6.17**	**82**	**0.20**	**10.3**
CD	**7.071**	**1.813**	**1.524**	**2.297**	**0.112**	**0.036**	**209.491**	**3.287**	**6.482**	**0.027**	**0.625**
SE(m)	**2.503**	**0.642**	**0.540**	**0.813**	**0.040**	**0.013**	**74.154**	**1.164**	**2.294**	**0.009**	**0.221**
SE (d)	**3.539**	**0.908**	**0.763**	**1.15**	**0.056**	**0.018**	**104.869**	**1.646**	**3.245**	**0.013**	**0.313**
CV	**5.557**	**11.984**	**9.750**	**7.498**	**13.003**	**16.524**	**7.563**	**16.713**	**6.482**	**7.509**	**3.684**

Table 3. Phenotypical and Genotypical correlation matrix

		FF	DM	PH	NB	IL	NIP	NSP	BY	EY	HI	TW	YP
FF	r_p	1.0000	-0.399**	-0.0504	0.0759	-0.465**	-0.268*	-0.2100	-0.338*	-0.2006	-0.1672	-0.551**	**-0.227***
	r_g	1.0000	-0.400**	-0.0510	0.0805	-0.497**	-0.270*	-0.2105	-0.342*	-0.2016	-0.1709	-0.561**	**-0.229***
DM	r_p		1.0000	0.541**	0.310*	0.818**	0.627**	0.634**	0.607**	0.593**	0.453**	0.749**	**0.499****
	r_g		1.0000	0.550**	0.317*	0.877**	0.633**	0.635**	0.612**	0.596**	0.461**	0.763**	**0.501****
PH	r_p			1.0000	0.1836	0.432**	0.670**	0.641**	0.548**	0.423**	0.1742	0.440**	**0.441****
	r_g			1.0000	0.1941	0.456**	0.687**	0.651**	0.560**	0.430**	0.1842	0.449**	**0.448****
NB	r_p				1.0000	0.428**	0.368**	0.437**	0.486**	0.266*	0.0084	-0.0054	**0.329***
	r_g				1.0000	0.486**	0.370**	0.445**	0.501**	0.274*	0.0110	0.0009	**0.335***
IL	r_p					1.0000	0.574**	0.633**	0.568**	0.598**	0.453**	0.601**	**0.595****
	r_g					1.0000	0.631**	0.677**	0.617**	0.637**	0.504**	0.648**	**0.633****
NIP	r_p						1.0000	0.664**	0.808**	0.520**	0.1417	0.397**	**0.570****
	r_g						1.0000	0.670**	0.826**	0.529**	0.1474	0.403**	**0.576****
NSP	r_p							1.0000	0.553**	0.701**	0.450**	0.458**	**0.754****
	r_g							1.0000	0.559**	0.703**	0.460**	0.465**	**0.758****
BY	r_p								1.0000	0.476**	-0.0320	0.418**	**0.410****
	r_g								1.0000	0.478**	-0.0360	0.435**	**0.415****
EY	r_p									1.0000	0.790**	0.542**	**0.574****
	r_g									1.0000	0.804**	0.554**	**0.580****
HI	r_p										1.0000	0.527**	**0.466****
	r_g										1.0000	0.552**	**0.481****
TW	r_p											1.0000	**0.414****
	r_g											1.0000	**0.423****
YP	r_p												1.0000
	r_g												1.0000

*** and * indicates significance at 1% and 5% level of significance respectively. r_p: Phenotypic correlation, r_g: Genotypic correlation, **FF**: Days to first flowering, **DM**: Days to maturity, **PH**: Plant height, **NB**: Number of branches per plant, **IL:** Inflorescence length, **NIP**: Number of inflorescences per plant, **NSP**: Number of seeds per plant, **BY**: Biological yield, **EY**: Economic yield, **HI**: Harvest index, **TW**: Test weight, **YP**: Yield per plot*

Table 4. Phenotypic and genotypic PATH matrix of yield per plot

		FF	DM	PH	NB	IL	NIP	NSP	BY	EY	HI	TW	YP
FF	**P**	**0.1042**	-0.0415	-0.0052	0.0079	-0.0484	-0.0279	-0.0219	-0.0352	-0.0209	-0.0174	-0.0574	-0.227*
	G	**0.1913**	-0.0766	-0.0098	0.0154	-0.0950	-0.0516	-0.0403	-0.0654	-0.0386	-0.0327	-0.1073	-0.229*
DM	**P**	0.1695	**-0.4254**	-0.2302	-0.1320	-0.3482	-0.2666	-0.2697	-0.2582	-0.2523	-0.1927	-0.3185	0.499**
	G	0.2401	**-0.5997**	-0.3298	-0.1903	-0.5258	-0.3797	-0.3811	-0.3670	-0.3572	-0.2762	-0.4578	0.501**
PH	**P**	0.0078	-0.0835	**-0.1544**	-0.0283	-0.0666	-0.1033	-0.0989	-0.0845	-0.0653	-0.0269	-0.0679	0.441**
	G	0.0089	-0.0954	**-0.1734**	-0.0337	-0.0791	-0.1192	-0.1128	-0.0971	-0.0746	-0.0320	-0.0778	0.448**
NB	**P**	-0.0027	-0.0108	-0.0064	**-0.0349**	-0.0149	-0.0129	-0.0153	-0.0170	-0.0093	-0.0003	0.0002	0.329*
	G	-0.0102	-0.0403	-0.0246	**-0.1269**	-0.0617	-0.0470	-0.0565	-0.0636	-0.0348	-0.0014	-0.0001	0.335*
IL	**P**	-0.1552	0.2732	0.1441	0.1427	**0.3338**	0.1915	0.2113	0.1897	0.1997	0.1513	0.2006	0.595**
	G	-0.2636	0.4655	0.2423	0.2581	**0.5310**	0.3351	0.3596	0.3277	0.3384	0.2678	0.3440	0.633**
NIP	**P**	-0.0878	0.2056	0.2197	0.1208	0.1883	**0.3281**	0.2180	0.2652	0.1707	0.0465	0.1302	0.570**
	G	-0.0794	0.1861	0.2020	0.1089	0.1856	**0.2940**	0.1970	0.2429	0.1554	0.0433	0.1185	0.576**
NSP	**P**	-0.1452	0.4384	0.4433	0.3021	0.4377	0.4594	**0.6916**	0.3823	0.4845	0.3110	0.3167	0.754**
	G	-0.1513	0.4568	0.4676	0.3200	0.4869	0.4816	**0.7189**	0.4016	0.5057	0.3307	0.3344	0.758**
BY	**P**	-0.0544	0.0977	0.0881	0.0783	0.0915	0.1301	0.0890	**0.1610**	0.0765	-0.0051	0.0672	0.410**
	G	-0.1106	0.1979	0.1811	0.1620	0.1996	0.2672	0.1807	**0.3234**	0.1545	-0.0117	0.1408	0.415**
EY	**P**	0.0989	-0.2923	-0.2087	-0.1312	-0.2949	-0.2564	-0.3453	-0.2344	**-0.4929**	-0.3894	-0.2674	0.574**
	G	0.1366	-0.4038	-0.2915	-0.1859	-0.4321	-0.3584	-0.4769	-0.3239	**-0.6780**	-0.5451	-0.3756	0.580**
HI	**P**	-0.0864	0.2339	0.0899	0.0043	0.2341	0.0732	0.2322	-0.0165	0.4080	**0.5164**	0.2721	0.466**
	G	-0.1131	0.3046	0.1219	0.0073	0.3337	0.0975	0.3044	-0.0238	0.5319	**0.6616**	0.3654	0.481**
TW	**P**	-0.0760	0.1033	0.0607	-0.0007	0.0829	0.0547	0.0632	0.0576	0.0748	0.0727	**0.1380**	0.414**
	G	-0.0778	0.1059	0.0623	0.0001	0.0899	0.0559	0.0646	0.0604	0.0769	0.0767	**0.1388**	0.423**
YP	**P**	-0.227*	0.499**	0.441**	0.329*	0.595**	0.570**	0.754**	0.410**	0.574**	0.466**	0.414**	**1.0000**
	G	-0.229*	0.501**	0.448**	0.335*	0.633**	0.576**	0.758**	0.415**	0.580**	0.481**	0.423**	**1.0000**
Partial R^2	**P**	-0.0237	-0.2121	-0.0681	-0.0115	0.1987	0.1870	0.5215	0.0660	-0.2827	0.2407	0.0571	
	G	-0.0438	-0.3005	-0.0777	-0.0425	0.3361	0.1692	0.5446	0.1343	-0.3930	0.3183	0.0588	

Residual effect: P: 0.272 and G: 0.244

***P**: Phenotypic, **G**: Genotypic, **FF**: Days to first flowering, **DM**: Days to maturity, **PH**: Plant height, **NB**: Number of branches per plant, **IL:** Inflorescence length, **NIP**: Number of inflorescences per plant, **NSP:** Number of seeds per plant, **BY**: Biological yield, **EY**: Economic yield, **HI:** Harvest index, **TW**: Test weight, **YP**: Yield per plot*

3.4 Correlation Coefficient

As stated in Table 3 the highest phenotypic and genotypic coefficient of variations were observed for number of seeds plant^{-1}, number of inflorescence plant^{-1}, economic yield, inflorescence length, days to maturity, harvest index and plant height indicated the scope of improvement through selection of these traits. While low to medium estimated were observed for test weight, biological yield and number of branches plant^{-1}. Similar findings were reported earlier by Bisht, A. S. et al*.,* [17,18], M. Dutta et al*.,* [21] and Debnath, N. R. et al*.,* [19].

3.5 Path Analysis

The path analysis revealed positive direct effect of number seeds plot^{-1}, harvest index, inflorescence length, number of inflorescence plant^{-1}, biological yield, test weight and days to first flowering with seed yield plot^{-1} at both phenotypic and genotypic level (Table 4). Similar findings were reported earlier by Kolaric et al*.,* (2021), Bisht, A. S. et al*.,* [17,18] and Dutta, M. et al*.,* [21].

3.6 Seed and Seedling Parameters

The germination test, tetrazolium test, electric conductivity test and protein content estimation were conducted on 24 genotypes of buckwheat. As per the result in Table 2 all seed and seedling parameters viz., germination percent (%), root length (cm), shoot length (cm), seedling length (cm), fresh weight (g), dry weight (g), vigour index I & II, viability percent (%), electric conductivity (dsm^{-1}) and protein content (g%) were found to be significant.

The genotype IC 42412 recorded highest germination percent (97%) and lowest was recorded by EC 125940 (73.5%). IC 107575 genotype measured maximum root length (13cm) and minimum was measured in EC 125940 (3.9cm). the genotype IC 42412 measured maximum shoot length (15.4cm) whereas minimum was measured in IC 341672 (9.1cm). The seedling length was observed to be maximum in IC 42412 (27.7cm) whereas minimum was observed in EC 125940 (15.7cm). The maximum fresh weight was observed in IC 42412 (1.05g) and minimum was recorded in EC 125940 (0.3g). The genotype IC 42412 recorded maximum dry weight (0.303g) whereas, minimum was recorded by EC 125940 (0.08g). The genotype IC 42412 recorded maximum vigour index I & II (2703 and 29.39) whereas minimum was recorded by EC 125940 (1159 and 6.17). The tetrazolium test result indicated that highest viability percent was recorded by IC 42412 (99%) and least viability percent was recorded by EC 125940 (84%). The electric conductivity test result states that less leachates conductivity (0.20 and 0.22 dsm^{-1}) was recorded by IC 329196 and IC 42412. The maximum leachates conductivity was recorded by IC 14889 (0.31dsm^{-1}). The seed sample leachates with less electric conductivity were referred to be highly vigorous. Of all genotypes, IC 42412 was highly vigorous genotype. The highest protein content was recorded by genotype IC 24300 (14.1g%) and least was recorded by IC 107616 (10.3g%). Similar findings were reported earlier by Sowmya, S. A. et al*.,* [15], Ocwa et al*.,* [22], Bisht, S. A. et al*.,* [17,18] and Carvalho, T. C. et al*.,* [23].

4. CONCLUSION

The overall performance of buckwheat genotypes under the present study judged on the basis of positive results obtained indicated that, IC 108508 was a superior genotype and produced maximum yield of 315g respectively, which was more that yield produced by PRB 1 i.e., 208.3g. At par genotypes namely IC26755, IC 37275 and IC258233 recorded yield little bit close to maximum yielded genotype. Hence, these genotypes can be suggested for commercial cultivation under agro-climatic regions of Prayagraj. Through correlation and path analysis it was clear that number of seeds plant^{-1}, inflorescence length, number of inflorescence plant^{-1}, plant height and days to maturity may be given due consideration during selection for crop improvement. The study of 24 genotypes under laboratory conditions stated that IC 42412 performed well in germination, tetrazolium and electric conductivity tests. So, it is considered as a physiologically potential genotype.

5. FUTURE PROSPECTS

The further investigation needs to be conducted for confirmation of promising genotypes for Prayagraj region. The genotypes IC 108508, IC 26755, IC 37275 and IC 258233 were found to be promising for cultivation under agro-climatic region of Prayagraj and hence, it can be useful for further crop improvement programme.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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